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IRRADIATION CREEP AND ITS FLUX DEPENDENCE ON NEAR ISOTROPIC GRAPHITE AT 850°C

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1. Introduction

An irradiation creep experiment has been performed on a sample of near isotropic H 451 graphite in the HFR at Petten. The irradiation was performed under tension in the axial direction at 850°C up to a fast fluence of $2{,}8 \times 10^{21}$ ncm^{-2} DNE and resulted in a final creep strain of 0,35%. This paper summarises the irradiation experience and analyses the results.

The purpose of the experiment was to investigate the dependence of the steady state creep rate on the applied stress and on the fast flux density. To achieve this, a single sample of the material was irradiated successively in two positions of the reactor having different flux levels. Clear evidence of a flux effect was observed in that the creep rate, defined as the strain per unit of stress and fluence, showed a strong decrease with increasing flux density.

2. Irradiation Device

Creep is measured continuously during the irradiation using a differential technique /1/. A single cylindrical sample is maintained under a tensile load by a pneumatic bellows system and the resulting dimensional change is compared with that of unstressed graphite reference shells (Fig.1). A sensor is moved alternately between the stressed and unstressed samples. This movement is induced by pneumatic bellows and is detected by a pair of linear displacement transducers. The in-core section of the machine comprises the irradiation samples and flux monitors in a graphite drum. The measuring system bellows and transducers are located out of core in the upper section of the machine. Out-of-pile equipment automatically records creep, sample load, and temperature.

3. Irradiation History

The irradiation was performed in both a low and a high flux position of the reactor. The stress was initially set at 4.56 MPa but after 1170 hrs it was increased to 5,98 MPa. The temperature was controlled in the range 820°C to 850°C throughout the irradiation. At 2700 hrs the measuring system became unreliable due to debris becoming trapped between the sensor and the sample.

4. Results

The irradiation device was well suited to perform elasticity tests both before and during irradiation. The results are shown in Fig.1. It can be seen that during irradiation the Young's Modulus undergoes an increase which is equal to or higher than increments measured on irradiated but unstressed samples of the same graphite Fig.2. This accords well with the dislocation model, and previous results /2/ indicating that creep causes no decrease in the Young's Modulus as long as no accelerated or tertiairy creep is taking place.

The creep strain and temperature are plotted as a function of neutron fluence and time in Fig.3. The transient creep at the start of the irradiation was low in comparison with other published results /3/ and the saturation dose was also low. However, it should be noted that in order to decrease the risk of failure during irradiation, a tensile test was performed before irradiation up to 80% of the quoted ultimate tensile stress /4/. A reasonably large permanent set, resulting in a high back stress, may have been introduced in the graphite /5/ which during the first step of irradiation had to be recovered and thus considerably reduced the transient creep. The transient creep contribution after the stress increase was in better agreement with that expected /3/. In the successive irradiation periods, reasonably accurate values for the steady state creep coefficient could be established Fig. 3.

It can be seen that on the one hand an increase in stress of approximately 30% has nearly no influence on the creep coefficient but on the other hand, it decreases with an increase in the neutron flux density. Both observations can be explained by the theoretical models for irradiation creep in graphite /6/ /7/, particularly the flux density dependence which was also demonstrated in the restrained shrinkage experiments /6/.

5. Conclusions

- The steady state creep rate is nearly independent of the applied stress
- The creep rate increases with decreasing neutron flux density (at least in the range (1.2×10^{14} $ncm^{-2}s^{-1}$)
- Transient and steady state creep has not caused mechanical deterioration of the graphite at fluences lower than 2.10^{21} ncm^{-2}.

6. References

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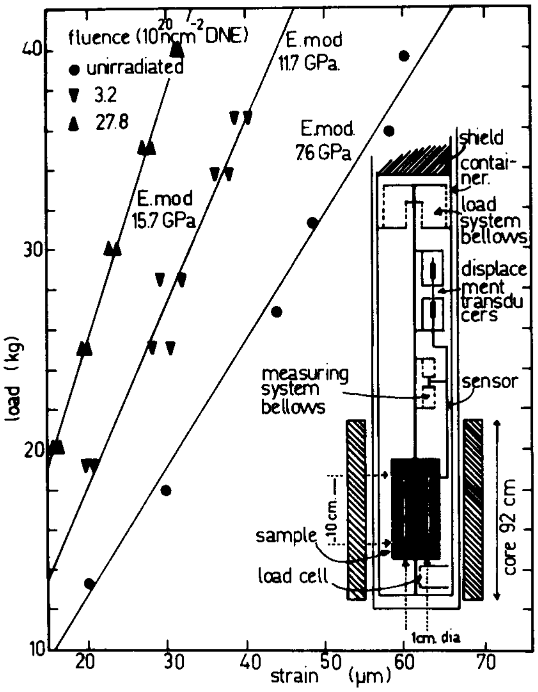

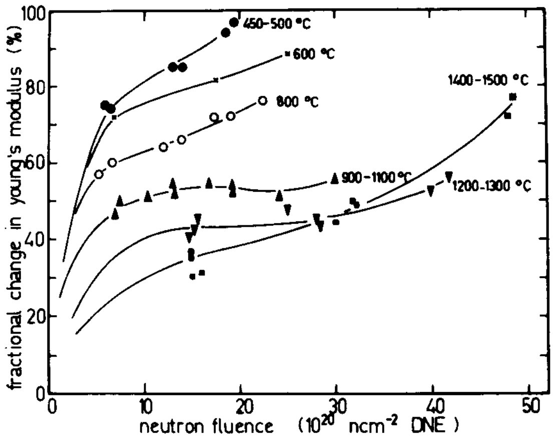

Fig.1 Load-deflection measurements before, during and after irradiation and schematic of strain registration system

Fig.2 Change in Youngs Modulus of H451 graphite for both head directions

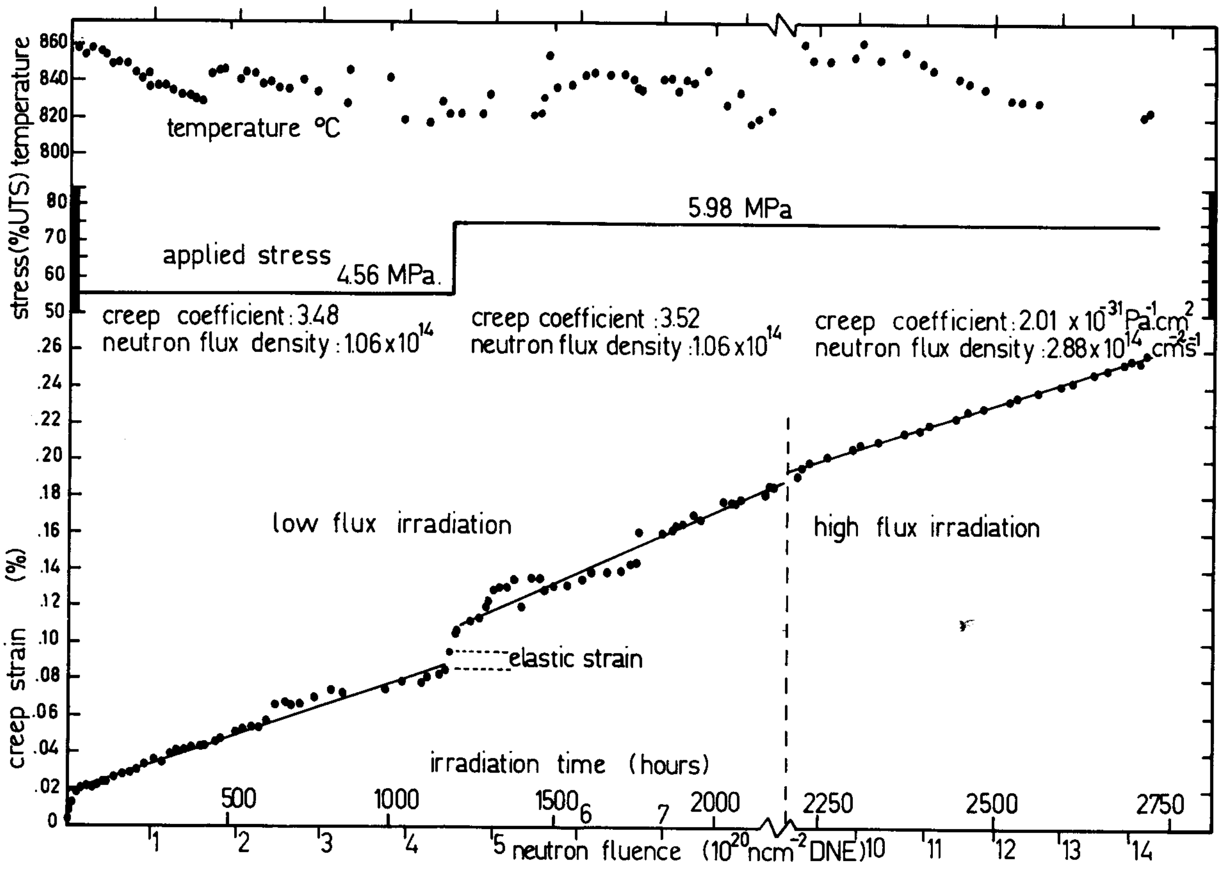

Fig.3 Irradiation History